DM ELECTRONICS MINIATURIZATION

CONTRACT NO. F29601-03-M-0257

DEFORMABLE MIRROR (DM)

ELECTRONICS MINIATURIZATION

MDA - AFRL

SBIR Phase I

QorTek

The foremost developer of small/high efficiency PZT/PMN drives.

Presently has contracts for - UAVs, large spacecraft, ABL, aircraft, helicopters, submarines, sonar, hull arrays, surface ships.

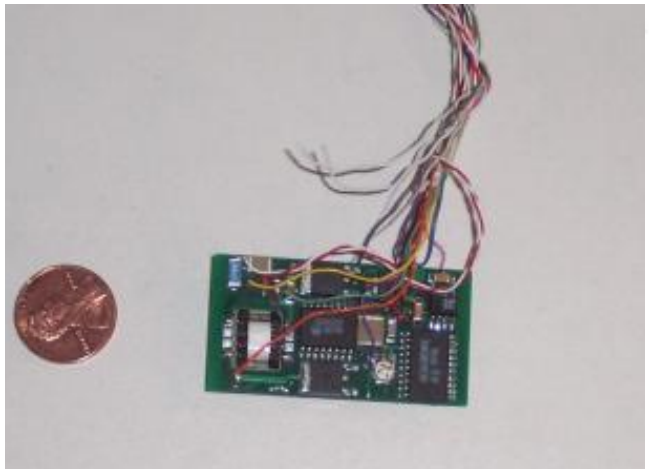
QorTek PZT/PMN drives are often approximately same size as the actuator itself.

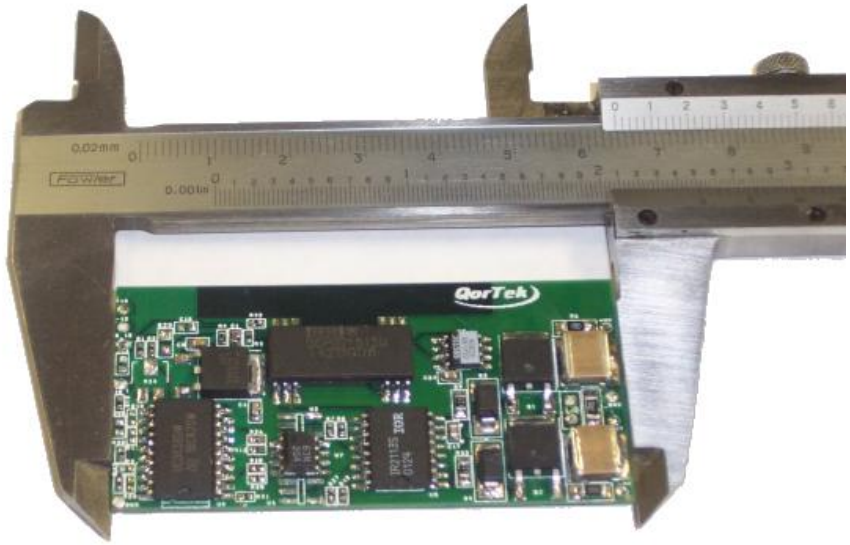
Is commercial supplier of power solutions to commercial PZT/PMN manufacturers

Working with aerospace primes to develop foundry core versions of its advanced proprietary/patented electronics

QorTek switch electronics match linear S/N performance

QorTek PMN/PZT Drives



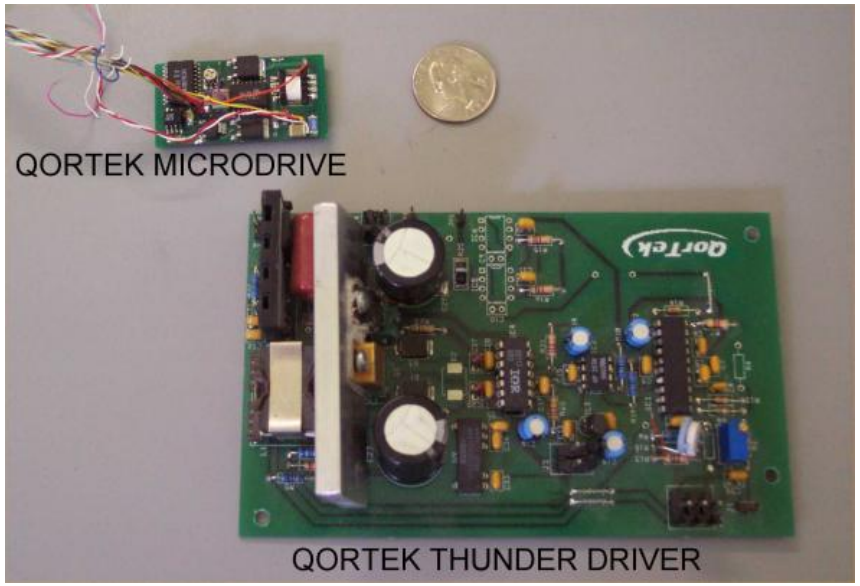


- Instantly impedance matches a capacitive load

- Is highly regenerative (up to 98% efficient) – i.e. No heat generation

- Extremely compact with small output filter

- Extremely flat response across many 10's of KHz and full power across the entire bandwidth



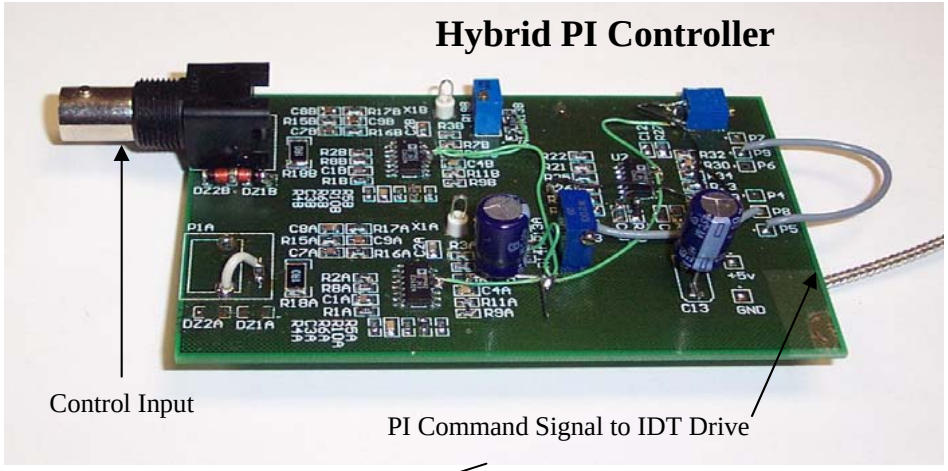
What is New?

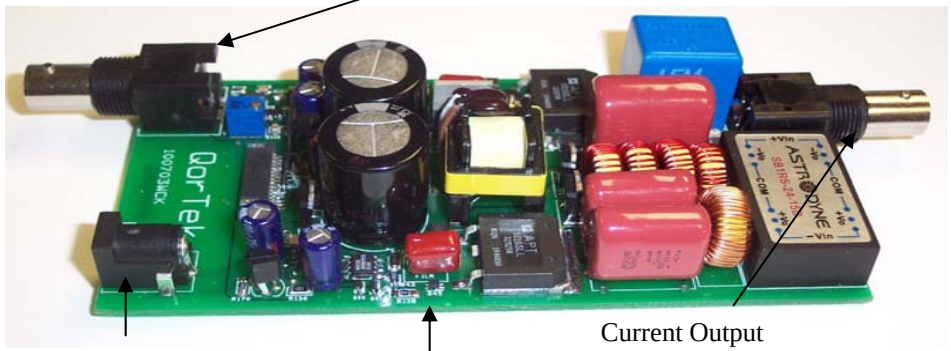
- High Bandwidth Operation (with full power delivery across bandwidth)
- Independent Actuator (mechanical/electrical load) Matching & Charge Isolation
- Large Reduction in Weight/Volume
- Elimination of Thermal Concerns
- Wiring and Wiring Interconnect Reduction
- Failure Modes Reduction
- ISO9002 Based Agile Manufacture With Complete Scalability, Automated Checking/ Failure Analysis
- Substantial Cost Reduction; Improved Repeatability
- High Density (actuator areal dominance) AO Device Packaging
- Internal (contactless) Independent Actuator Position Sensing
- 0.8 cu. in/0.1 oz total system cost (power + wiring + interconnects + digital control + substrate + i/o) per channel for a 10^2 - 10^3 PMN/PZT actuators
- Fully Integrated Lightweight (plug-n-play) Adaptive Optic Modules

Synthetic Power Source

Everything starts with use of QorTek proprietary and patented Synthetic Current Source Technology

Synthetic Q-Core uses proprietary & patented new switching topology concepts of POLYBRIDGE® and IDT™ to enable impedance match, low parts count, noise elimination, compact low profile implementation, SiC component integration etc



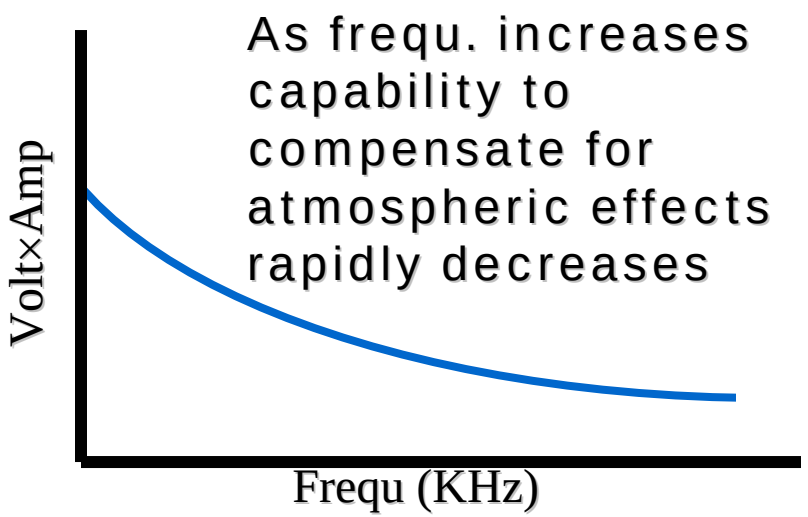


Full-power Bandwidth

Present MDA/NASA/AFRL AO sources are NOT Full-Power Bandwidth.

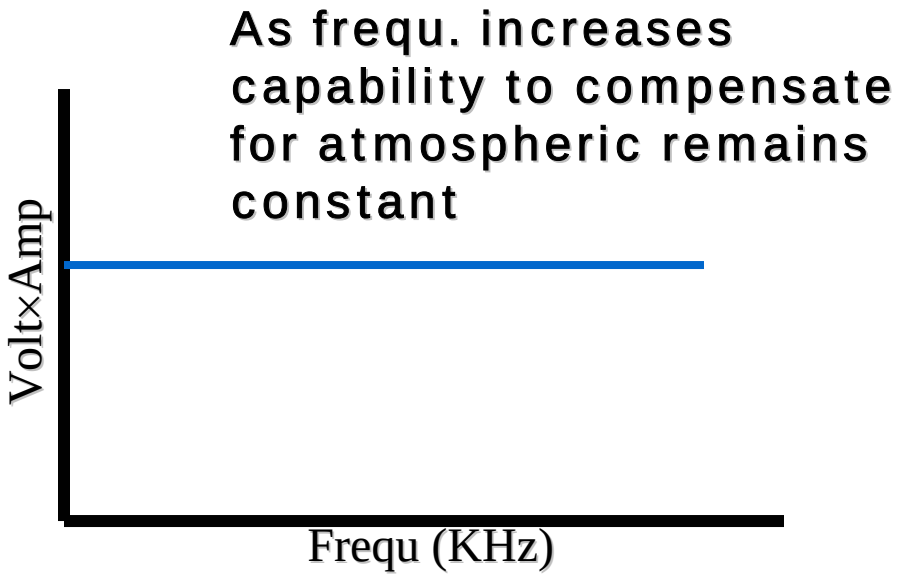
EXISTING SOURCES

- Electronic components stress occurs at higher frequ. operation
- Non-flat response must be integrated into a sourced or multiplexed system feedback



SYNTHETIC Q-CORE

-Electronic components stress doesn't increase with frequ.
- Flat response means simplified operation



Going From 1 to 1K Devices

Synthetic source is an ideal driver for a PZT/PMN type actuator. Multiplexing causes degradation in performance, introduces linear (heat generating devices), layers of complexity and expense, wiring harness issues, reliability questions, major drop in effective system bandwidth and power×bandwidth product.

How can we go from 1 to 1K and retain all the exemplary attributes of synthetic drives without all the disadvantages of multiplexing?

Solution is to install a single Impedance-Matched Synthetic Q-Core behind a Matrix-Like Array of extremely fast switches

Ultrafast Matrix Execution

How does a switching current source work? The current source is charged to a set current then switched into the many actuators. Each actuator either consumes some charge, or supplies charge to/from the source. The current source is charged/discharged as needed.

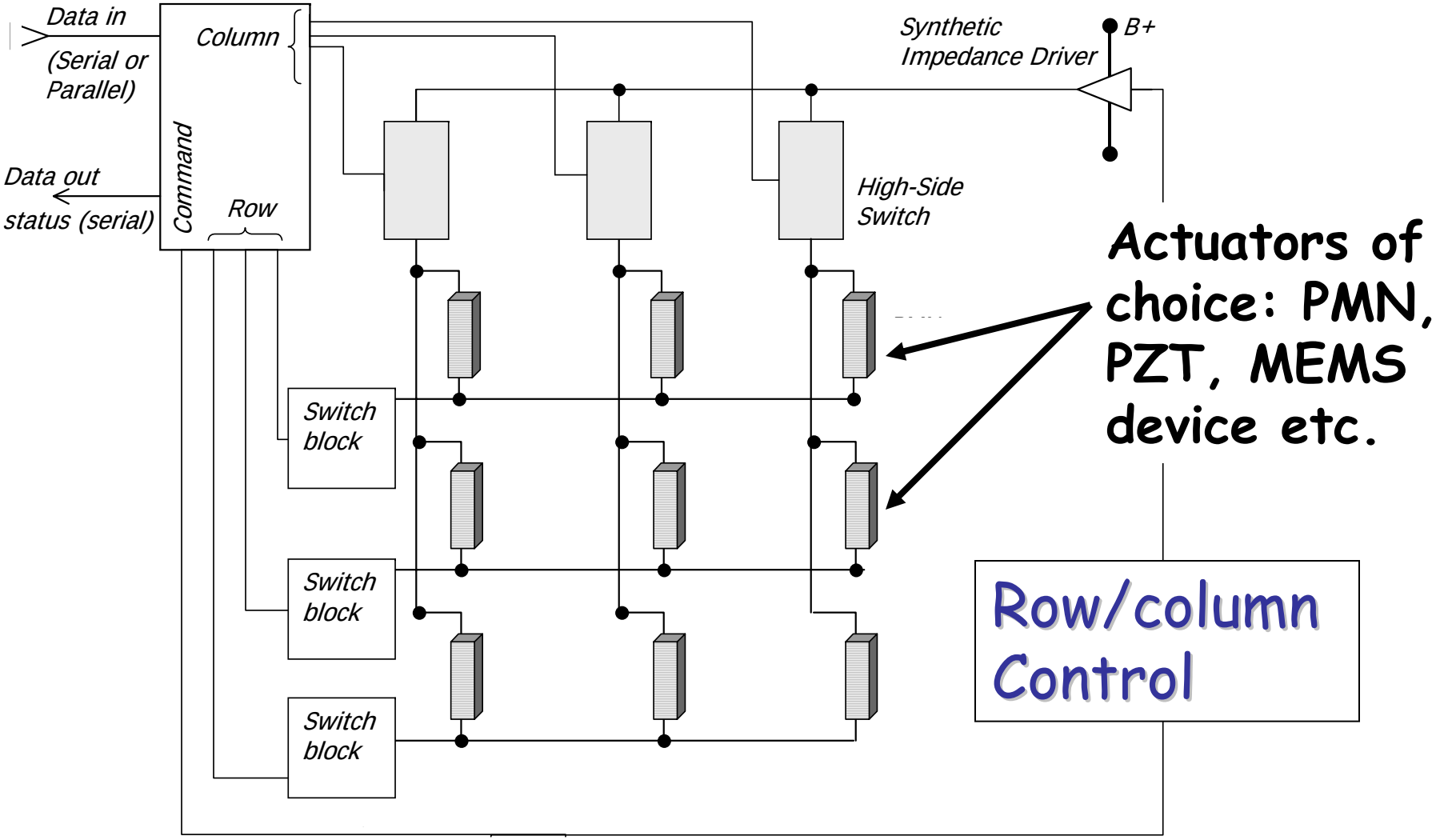
THUS-ALL WE SHOULD EVER CARE ABOUT IN REGARD TO THE SOURCE IS AMOUNT OF CHARGE USED BY THE ACTUATOR

-ij-th actuator looking back into the synthetic Q-Core source sees a perfectly impedance matched power source

-Q-Core can deliver a duty cycle on its ij-th switches almost to the breaking point of the actuator power bandwidth product

- ij-th actuator is unaware that 999 other actuators are NEARLY SIMULTANEOUSLY experiencing the same matched impedance and and the same high-bandwidth drive from the SAME source

Ultrafast Matrix Architecture

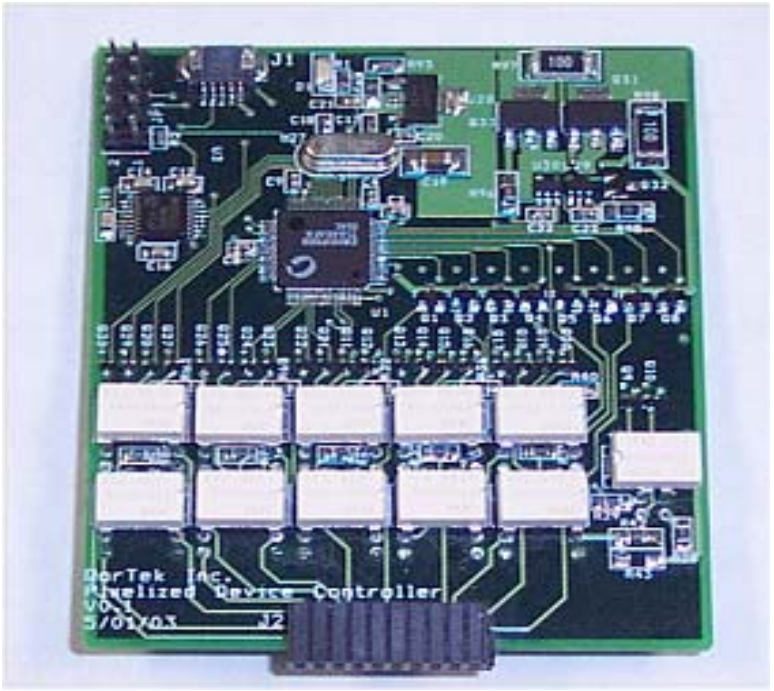


This is <u>not</u> analogous to how visual displays work

Functional Matrix Architecture

CLARIFICATION: All the power, control and signal extraction for 1,000+ sensors and actuators on a proposed AO system can be implemented by a Matrix Controller. The Matrix Controller has 3 wires (gnd, DC, signal).

NOTE: FMA installed systems have NO wires harness requirements.



QorTek Matrix Controller*:

*8 grams weight cost but provides power+i/o+control to up to 1,000 separate matrix devices using a consolidated (Q-Core) power supply concept**

Wiring / Interconnect Elimination

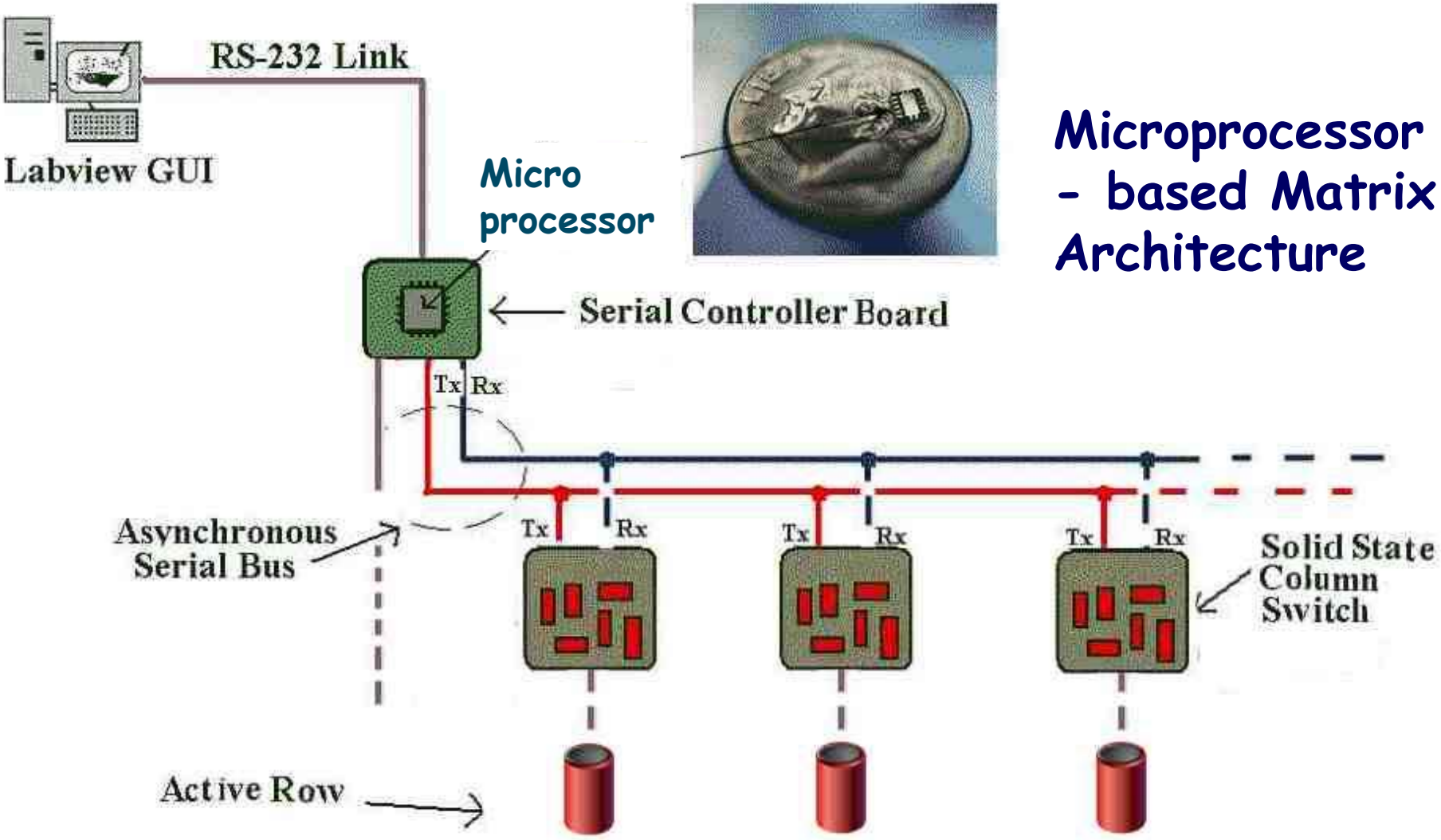
ISO9002 electronics manufactures can lay down a trace architecture on either rigid, semi-flex or flex substrate at extremely low cost. Typical board costs would be $5-$15 in quantity production and would include:

- ***Pre-fabricated electroding***
- ***Flex cable interconnect***
- ***All matrix trace architecture***

Pick and place procedures already exist for placement of multilayer capacitors (i.e. PZT or PMN actuators) and can optionally include the switches themselves.

Modern plants incorporate sophisticated auto check, and failure analysis tools for increased reliability over present day hand assembly

Ultracompact Control Architecture



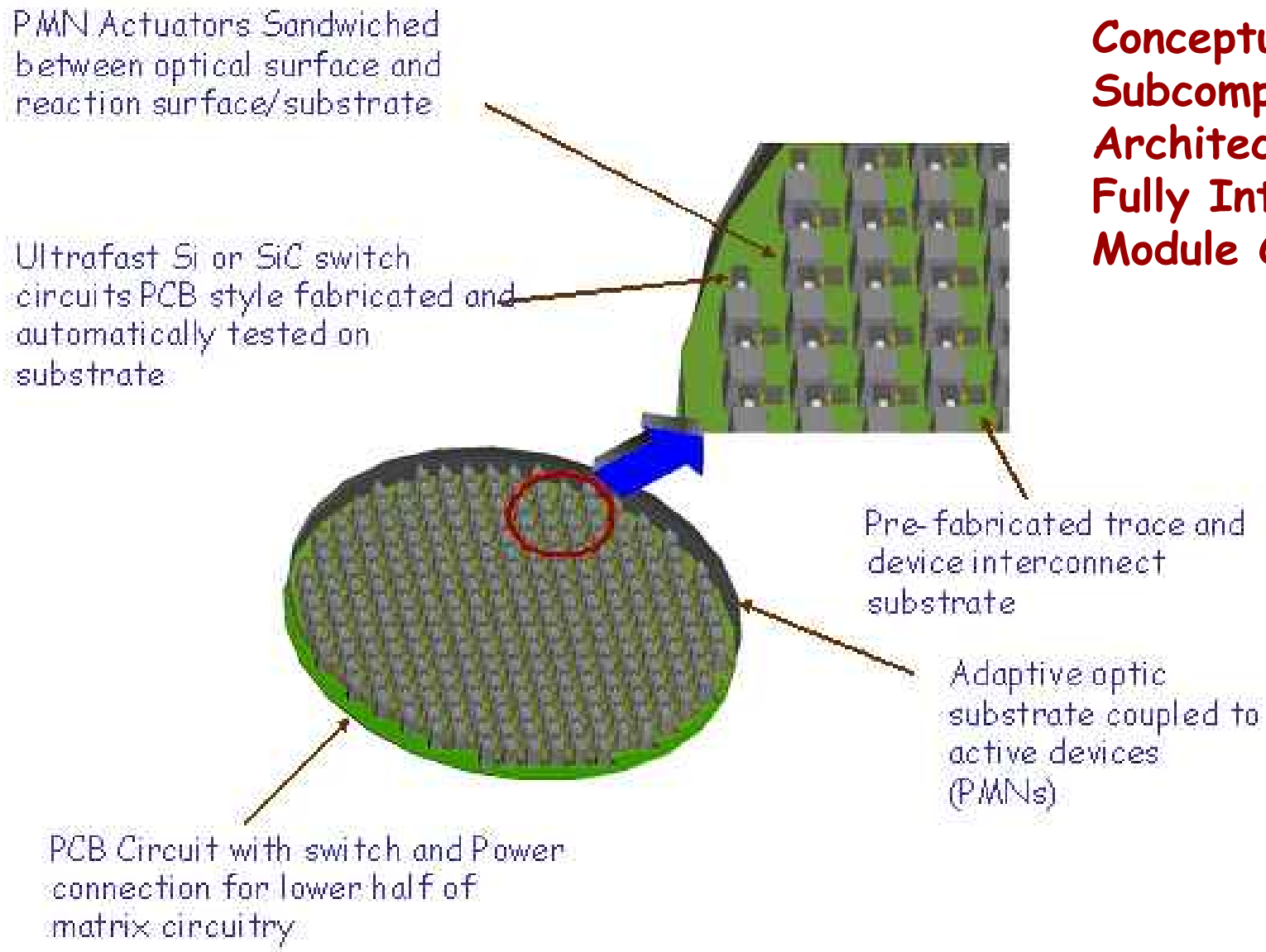
Microprocessor - based Matrix Architecture

Comparison to Advanced

Adaptive Optic Electronics Package Specifications	AFRL/MDA DM Goal	Matrix Goal	Matrix Results
Driver size/actuator [1]	1 cu. in.	0.5 cu. in.	0.08 cu. in. [2]
Electronic package weight/actuator	2 oz.	1 oz.	<0.24oz.* <0.1 oz.
Strain (PMN-PT multilayer ceramic)	4 μ-m@2kHz	4 μ-m@200Hz	5 μ-m@1kHz
Lag	3°@2kHz	2°@200Hz	< 1°@1kHz
Strain (PMN-PT multilayer ceramic)	1 μ-m@10kHz[3]	1 μ-m@1kHz	2 μ-m@5kHz
Lag	50°@10kHz	20°@1kHz	< 8°@5kHz

1. Based on 256 actuators
2. Include all: power conduits (except for external buss power, gnd, and command signal connections), device interconnects, power electronics, digital processors, backplane electronics substrate.
   *includes PMN actuators
3. Above 5kHz it was noted that with a constant full-power synthetic drive PMN actuators begin to fail

Next Generation DM's

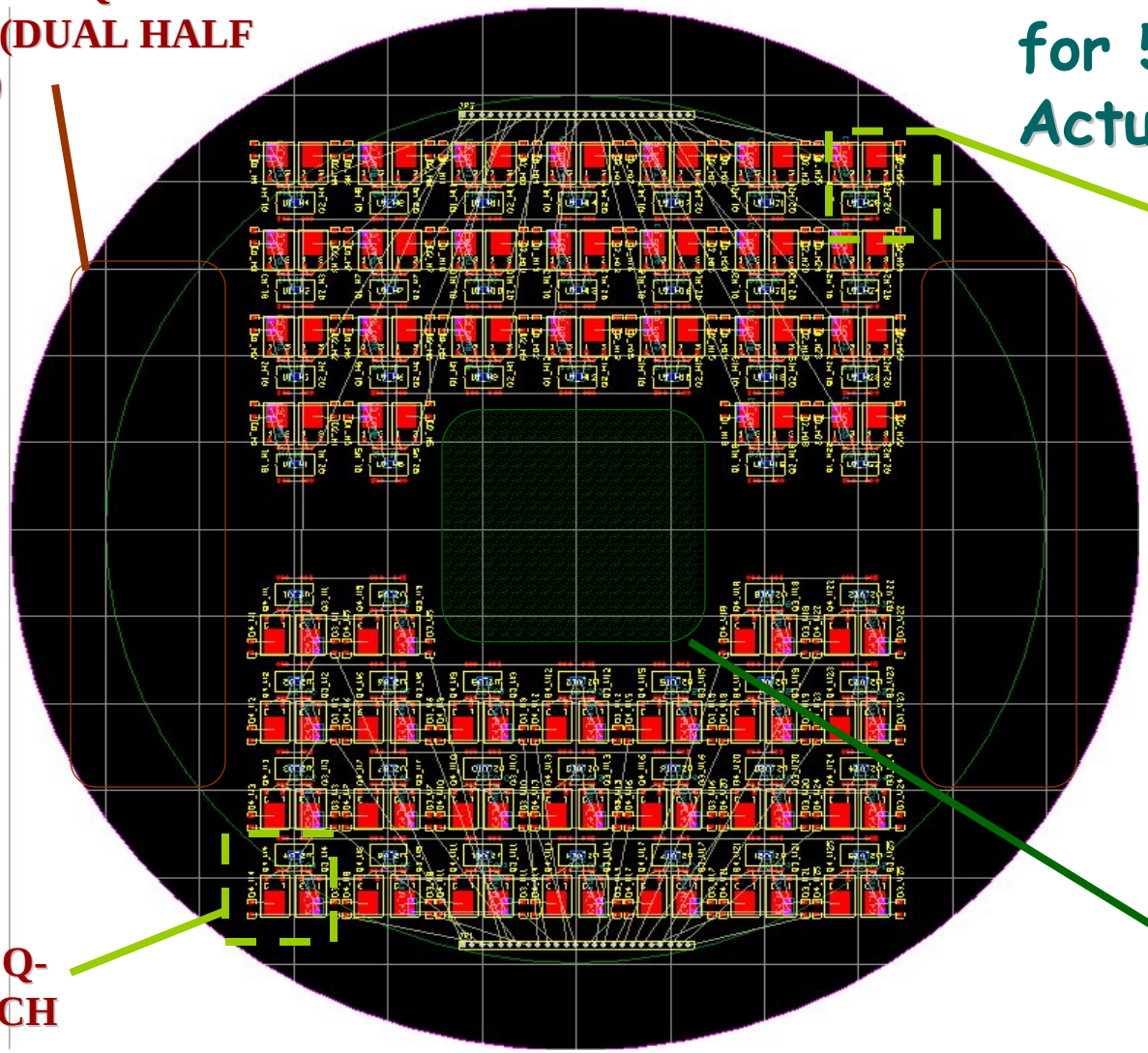


Conceptual Phase II Subcompact Matrix Architecture-based, Fully Integrated AO Module Concept

Advanced Q-Switch Layout

SYNTHETIC Q-CORE DRIVER (DUAL HALF BRIDGE)

12" Board Layout for 525 PMN/PZT Actuators



COLUMN Q-SWITCH

Control positioned behind DM

FPGA/DSP CONTROLLER

ROW Q-SWITCH

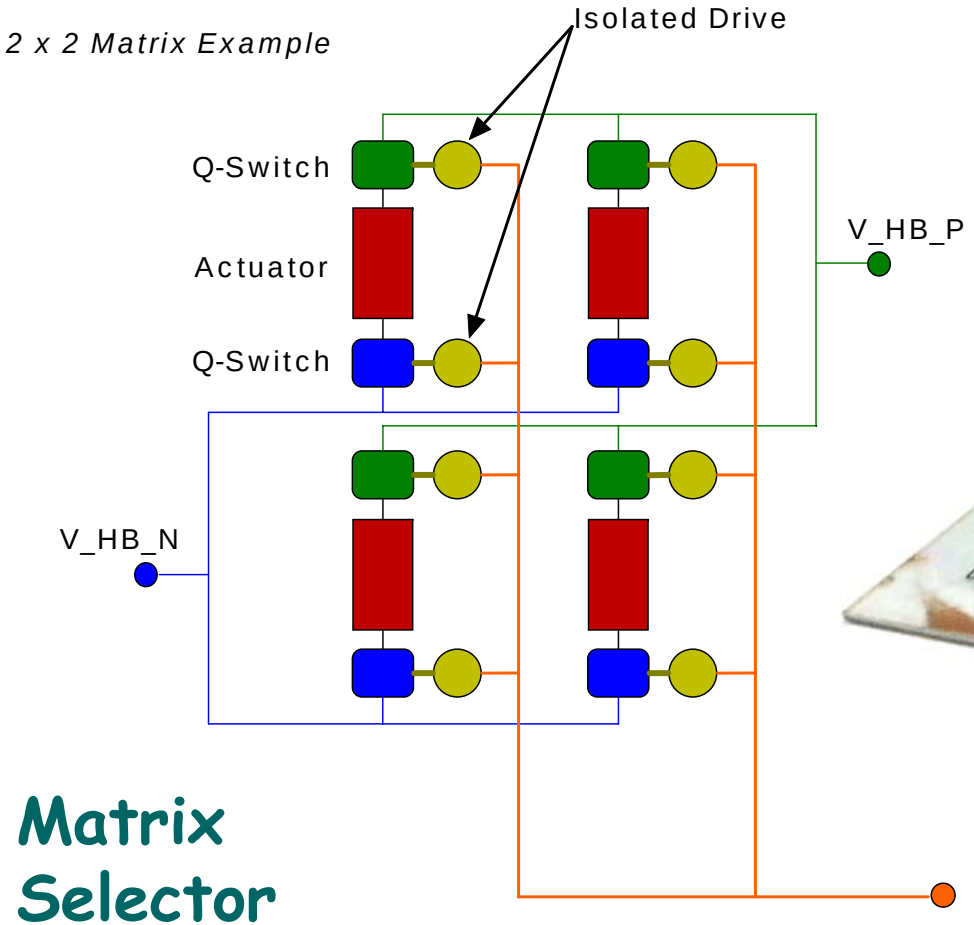
CONTRACT NO. NNG04CA10C

PIXELIZED DEVICE CONTROL

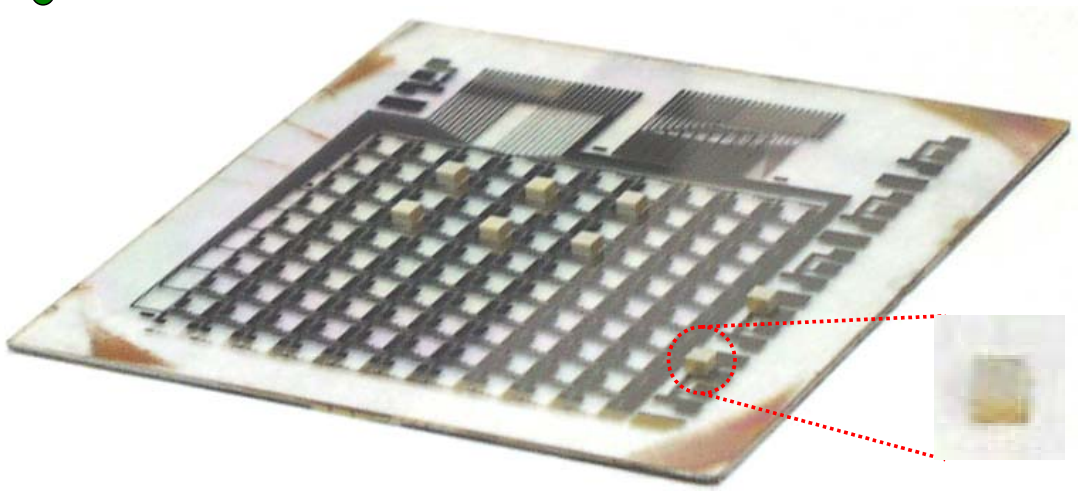
NASA SEC GSFC

SBIR Phase II

Phase I Results



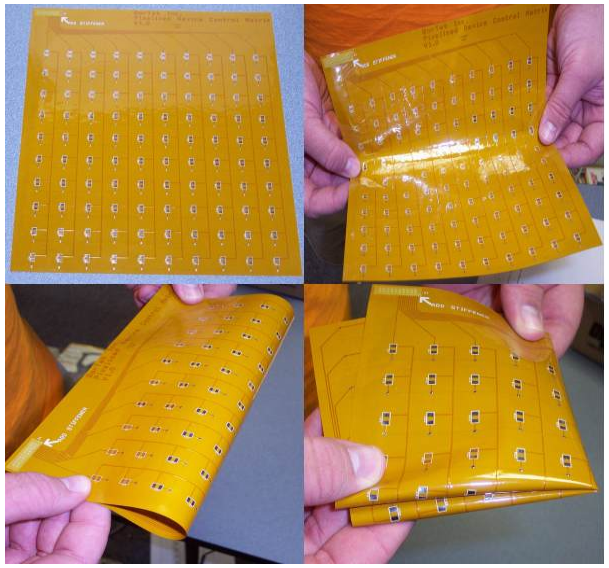
Matrix Selector Architecture



100 Actuator Prototype on Glass Substrate

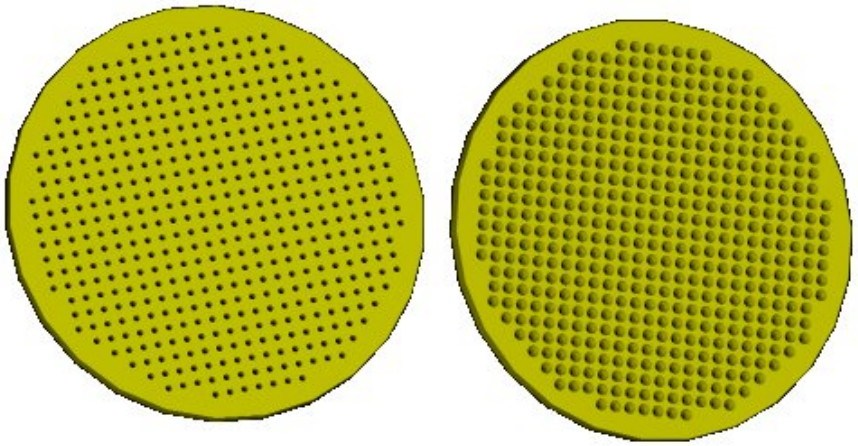
PIXELIZED DEVICE CONTROL PHASE II GOALS

- Power Electronics Size Reduction
- Reduction of Wiring via Flex Circuit
- Integrated Actuation and Control
- Increased reliability/usability for rapid mission technology infusion
- Low cost and scalability for cross mission applications

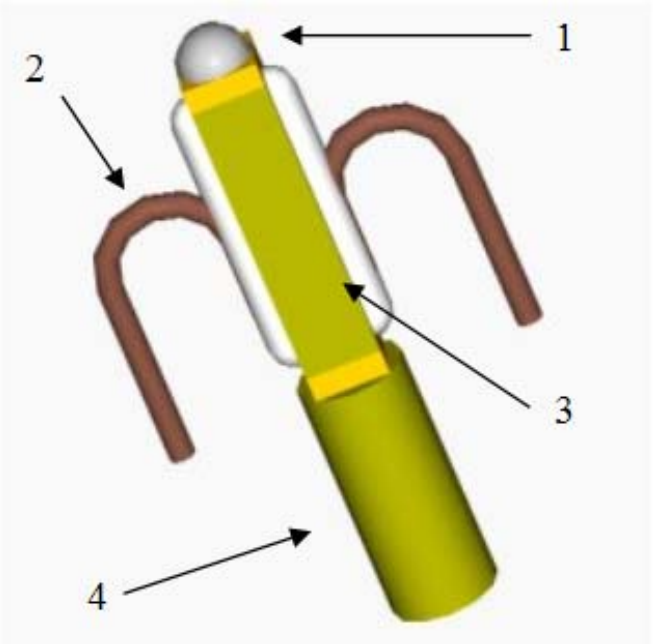


QorTek Developed 10x10 Interconnect Array

DM Mirror Construction



Reaction Plate Front (left) and Back (right) View

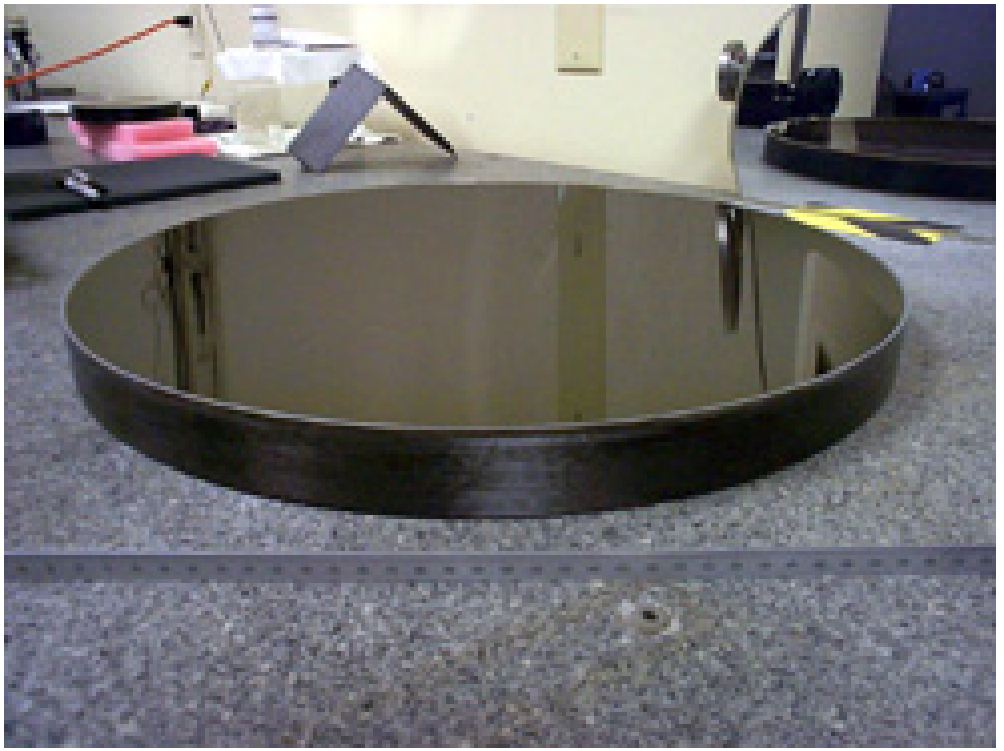


1	Hemispherical Head
2	Electrical Connections
3	PMN (ES-91) Actuator
4	Composite Leveling Peg

Actuator Construction

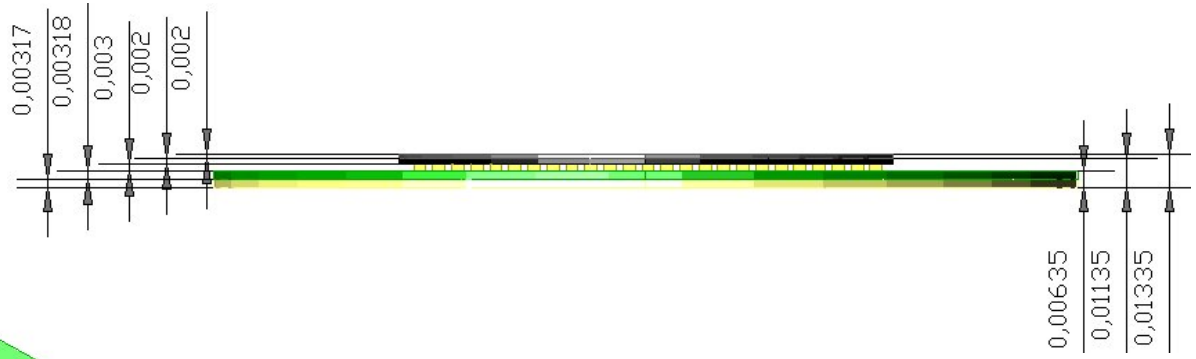
Phase II Mirror Development

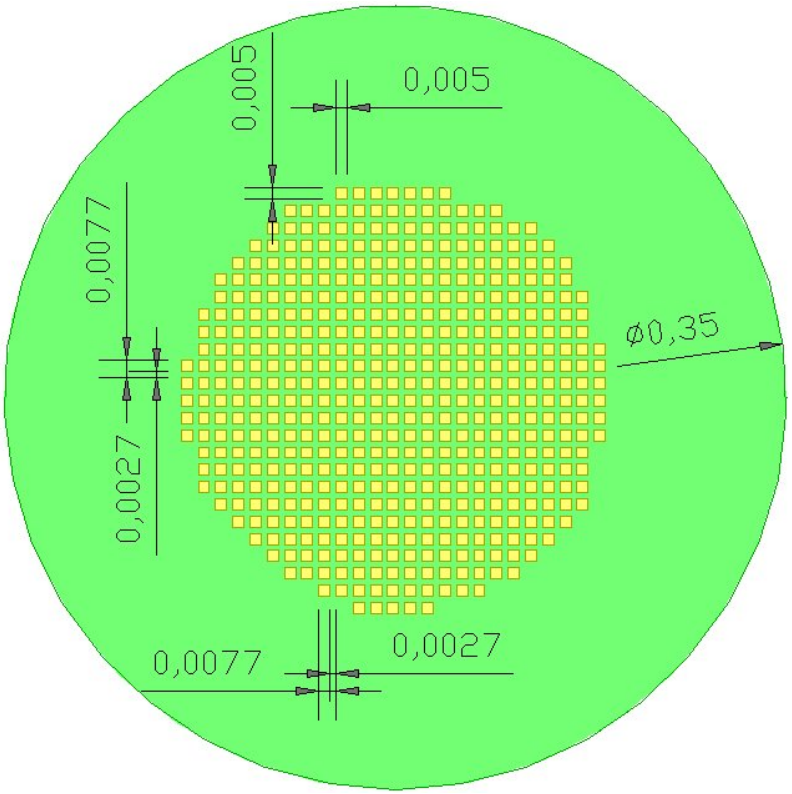
- Composite Mirror Applications (CMA) developing mirror face sheet laminate
- The laminate is a very thin (~30-500 microns) layer of pure resin
- Resin layer composite mirrors can be super-smooth and can have very low mid-frequency ripples



50cm Diameter 0.9mm Thick
f/1.9 Spheical Mirror

SCMA Devices with Interdigitated Electroding





Geometry configuration

- 3mm clearance between each actuator in the row direction
5mm clearance in the column direction